

QA:QA

**U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
OFFICE OF QUALITY ASSURANCE**

AUDIT REPORT M&O-ARP-00-04

OF THE

**CIVILIAN RADIOACTIVE WASTE MANAGEMENT SYSTEM
MANAGEMENT AND OPERATING CONTRACTOR**

LAWRENCE BERKELEY NATIONAL LABORATORY

AND

U.S. GEOLOGICAL SURVEY

AT

BERKELEY, CALIFORNIA

JANUARY 24-28, 2000

Prepared by: _____ **Date:** _____

**Robert F. Hartstern
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Approved by: _____ **Date:** _____

**Robert W. Clark
Director
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1.0 EXECUTIVE SUMMARY

This performance-based Quality Assurance (QA) Audit was conducted on the processes and activities related to the Unsaturated Flow and Transport (UZ) Process Model Report (PMR) being developed by the Civilian Radioactive Waste Management System Management and Operating Contractor (CRWMS M&O), Lawrence Berkeley National Laboratory (LBNL), and the U. S. Geological Survey (USGS). The audit was conducted at LBNL in Berkeley, California, January 24 through 28, 2000. The purpose of the audit was to evaluate the effectiveness of the Analysis and Model Report (AMR) process and the quality of the four AMR products selected from the 24 AMRs that constitute the UZ PMR.

The audit evaluated three AMRs being developed by LBNL and one by the USGS. It should be noted that while the process activities were evaluated to the extent possible relative to the UZ PMR, the supporting AMRs and PMR were in draft form, with the exception of the AMR U0000, "Development of the Numerical Grids for the UZ Flow and Transport Model," Revision 00.

The audit team determined that the CRWMS M&O and LBNL have effectively implemented critical process steps relative to the UZ activities, with the exception of the four Deficiency Reports (DR) LVMO-00-D-036 through 039 issued on software use and control by the CRWMS M&O, LBNL, and the USGS. Based on the evaluation of AMR U0010, "Simulation of Net Infiltration for Modern & Potential Future Climates (Infiltration Model)," developed by the USGS, a number of technical inadequacies were identified, in addition to software deficiencies, which resulted in the issuance of DR. USGS-00-D-034.

Overall, the audit team identified a total of seven deficient conditions, which resulted in the issuance of five DRs, and two deficient conditions requiring only remedial actions were Corrected During the Audit (CDA). DRs LVMO-00-D-036 through 039 were issued for the ineffective implementation of software controls: two pertain to the use of software not adequately incorporated by Configuration Management; one is for the use of unqualified software; and one is for inadequate documentation to support verification of software macros and routines. These deficient conditions continue to support the basis for the unsatisfactory verification of Corrective Action Request (CAR) LVMO-98-C-006. DR USGS-00-D-034 is specific to the adequacy of the AMR U0010, developed by the USGS. A deficient condition for incorrect recording of the technical reviews of Scientific Notebooks (SN) was considered to be isolated and was corrected. The last deficient condition was that AMR U0000's latest Document Input Reference System (DIRS) list has eliminated two macros that were listed in the DIRS for the approved Revision 0 of the AMR. This was also considered to be isolated and was corrected. Additionally, six recommendations are provided to the CRWMS M&O, LBNL and the USGS for administrative process and technical transparency improvements. Details of the deficient conditions and recommendations are presented in Sections 5.0 and 6.0, respectively.

Based upon reviews of in-process documentation, interviews of personnel, and examination of procedure processes, the audit team determined that UZ activities being conducted by the CRWMS M&O and LBNL at the time of the audit meet Office of Civilian Radioactive Waste Management QA program requirements, with the exception of software control. The audit team determined that the UZ activities performed by the USGS were found to be unsatisfactory.

2.0 SCOPE

The audit was conducted to evaluate the effectiveness of the AMR process for the development of the UZ PMR. The audit team evaluated the documented activities that constitute scientific and performance assessment analyses and models pertaining to the UZ. The related AMRs and supporting documents were examined to determine the effectiveness of the analysis in providing evidence to support the UZ PMR.

The UZ AMRs constitute the UZ PMR, which will support the Total System Performance Assessment on the subject and serve as an important reference to the License Application. The following processes and products were examined as part of this audit:

- WWP-NBS-HS-000002, dated 10/8/99, Work Package Planning Summary, “UZ Flow and Transport Process Model Report FY00, Work Package 1401213UM1, Revision 00”
- WWP-NBS-HS-000004, dated 10/8/99, Work Package Planning Summary “USGS UZ Flow and Transport Process Model Report FY00, Work Package 8191213UU1, Revision 00”
- TDP-NBS-HS-000009, Revision 00, Development Plan, “Unsaturated Zone Flow and Transport PMR”
- TDP-NBS-HS-000001, Revision 00, Development Plan, “Development of the Numerical Grids for the UZ Flow and Transport Model”
- TDP-NBS-HS-000016 Revision 0, Development Plan, “Simulation of Net Infiltration for Modern and Potential Future Climates”
- TDP-NBS-HS-000006, Revision 00, Development Plan, “*In Situ* Field Testing of Processes”
- TDP-NBS-HS-000005, Revision 00, Development Plan, “Seepage Calibration Model and Seepage Testing Data”
- ANL-NBS-HS-000015, Revision 00, “Development of the Numerical Grids for the UZ Flow and Transport Model” (AMR U0000)

- ANL-NBS-HS-000032, Draft 00A, “Simulation of Net Infiltration for Modern and Potential Future Climates” (AMR U0010)
- ANL-NBS-HS-000005, Revision 00E (Draft), “*In Situ* Field Testing of Processes” (AMR U0015)
- ANL-NBS-HS-000004, Revision 00D (Draft), “Seepage Calibration Model and Seepage Testing Data” (AMR U0080)

The audit team conducted personnel interviews and examined documentation in accordance with the approved audit plan to evaluate the adequacy and effectiveness of the critical process steps for the development of the AMRs that support the UZ PMR.

2.1 Process Steps/Products/Documentation

The performance-based audit evaluation of effectiveness was based upon the following:

1. Satisfactory completion of the critical process steps
2. Documentation that substantiates quality and traceability of data
3. Performance of trained and qualified personnel
4. Implementation of applicable QA Program elements

The following critical process steps were considered during the evaluation of the AMR process:

- Resources:
 - Planning (Work Package Planning Summaries [WPPS]/Development Plan [DP])
 - Personnel: Use of knowledgeable, capable, competent individuals; qualification requirements
 - Equipment (i.e., software programs)
- Methodology
 - Protocols (instructions, procedures, scientific notebooks)
 - Assumptions/scoping
 - Gathering of information/data acquisition
 - Assimilation, categorization, data reduction
 - Analyses, modeling
 - Products: models, reports, design input
 - Validation of Models – technical aspects

- Qualification of Data
 - To Be Verified (TBV)
 - Submittal to Technical Data Management System (TDMS)
 - Validation of Models – Data acceptance
- Adequacy & Accuracy
 - Checks and reviews (internal & external)
 - Evaluations
 - Approval
 - Revisions and changes
- Deliverables:
 - Scientific Investigations (i.e., Models)
 - Analyses/reports
 - Record submittals

2.2 The audit included a technical evaluation of the adequacy and effectiveness of the AMR/PMR process. Details of the technical evaluation are documented in Section 5.4 of this report.

3.0 AUDIT TEAM MEMBERS/OBSERVERS

Robert F. Hartstern, Office of Quality Assurance (OQA), Las Vegas, NV,
Audit Team Leader
Michael J. Eshleman, OQA, Las Vegas, NV, Auditor
Richard E. Powe, OQA, Las Vegas, NV, Auditor
Lester W. Wagner, OQA, Las Vegas, NV, Auditor
Keith M. Kersch, CRWMS M&O, Science Applications International Corporation,
Castle Rock, CO, Technical Specialist
Ronald M. Linden, Management Technical Support, Golder Associates, Inc.,
Las Vegas, NV, Technical Specialist

There were four observers present during the audit:

Ted Carter, U. S. Nuclear Regulatory Commission (NRC), White Flint, MD
Robert Latte, NRC, White Flint, MD
Jeffery Ciocco, NRC, White Flint, MD
Randy Fedors, NRC, Center for Nuclear Waste, Regulatory Analysis, San Antonio, TX

4.0 AUDIT MEETINGS AND PERSONNAL CONTACTED

A pre-audit meeting was conducted at LBNL, Berkeley, California, on January 24, 2000. A second pre-audit meeting was conducted specifically for the USGS personnel on January 26, 2000, since they were absent during the first pre-audit meeting.

Daily debriefings were held to apprise the audited organizations' management and staff of the progress of the audit and any potential conditions adverse to quality. A post-audit meeting was conducted at LBNL, Berkeley, California, with a video conference to the CRWMS M&O offices in Las Vegas, Nevada, on January 28, 2000.

Personnel contacted during the audit, including those that attended the pre-audit and post-audit meetings, are listed in Attachment 1, "Personnel Contacted During the Audit."

5.0 SUMMARY OF AUDIT RESULTS

5.1 Program Effectiveness

The audit team concluded that critical process steps applicable to the AMR/PMR process were effectively implemented; however, deficient conditions were identified relating to the implementation of software controls by the CRWMS M&O, LBNL and USGS, and deficient conditions identified for procedure implementation by the USGS. This resulted in the issuance of five DRs. There were also two CDAs identified. Details of these deficient conditions adverse to quality are presented in Section 5.5 of this report. In addition, six recommendations are provided in Section 6.0 of this report.

5.2 Stop Work or Immediate Corrective Actions Taken

There were no Stop Work Orders or immediate corrective actions taken as a result of the audit.

5.3 QA Program Activities

Attachment 2, "Summary Table of Audit Results," provides results for each critical process step evaluated. Attachment 3, "Summary Table of Audit Results for Procedure Compliance Evaluations," provides the results of procedure compliance evaluations. Details of the audit, including the objective evidence reviewed, are documented in the audit checklist. The checklist is maintained as a QA Record.

5.4 Technical Audit Activities

The UZ PMR will be developed using the input from 24 AMRs. To evaluate the effectiveness of the process, four AMRs were selected to be evaluated based on state of completion and how critical they were to the PMR. Three of the AMRs are being developed at LBNL and one at USGS (U0010). These reports were in various stages of completion and only AMR U0000 had been finalized. In examining the work in progress, the audit team reviewed the AMRs, laboratory SNs, pertinent records, and conducted interviews of the principal investigators and other key personnel.

Planning

Planning for the development of the four AMRs evaluated was found to be adequate. The required QAP 2.0 Activity Evaluations to determine that the work was subject to DOE/RW-0333P, Rev. 8, "Quality Assurance Requirements and Description" requirements were issued for both Fiscal Year (FY) 1999 and FY 2000 Work Packages (WP). WPPSs and DPs were issued for the AMRs evaluated and for the UZ PMR.

Personnel

Training and qualifications of LBNL personnel were found to be adequate. Verification was achieved through the performance of the individuals, their knowledge of the AMR development process, and the review of documented training and qualification records. However, personnel from the USGS did not appear to be aware of the latest changes to procedures applicable to the AMR/PMR development. See DR USGS-00-D-034.

Equipment/Software

All four AMRs evaluated had one or more software deficiencies. For details see Section 5.4.4, CAR LVMO-98-C-006, and the individual AMR summaries in this Section under Methodology.

Methodology

The technical evaluation results of the methodology for developing each of the four AMRs are as follows:

AMR U0000, Development of the Numerical Grids for the UZ Flow and Transport Model

The purpose of AMR U0000 is to provide numerical grids of the unsaturated hydrogeologic system beneath Yucca Mountain in accordance with DP TDP-NBS-HS-000009, Revision 00, WP 14012027M2). The resulting numerical grids, developed using current geologic, hydrogeologic, and mineralogic data, provide the necessary framework to: 1) develop calibrated hydrogeologic property sets and flow fields, 2) test conceptual hypotheses of flow and transport, and 3) predict flow and transport behavior under a variety of climatic and thermal loading conditions which are an integral part of the development of the UZ model. The development of the numerical grids had some software deficiencies as documented in DRs LVMO-00-D-038 and LVMO-00-D-039, but overall represents a sound technical product. The work was well presented, thorough, and well thought out. The sources of some of the equations presented in the AMR

were not clear. These were clarified during the audit by writing memos that will be part of the record package for this analysis (Recommendation #1). Future revisions of the report should have these clarifications added. The authors and support staff were very helpful and responsive to discussions conducted during the audit. They demonstrated a good understanding of the QA program within the Yucca Mountain Project.

Model validation for the scope and purpose of the model was determined to be sufficient. Because numerical grids are frameworks that alone do not capture physical processes/phenomena, "model validation" in the strictest sense does not apply. The process of grid "verification" (an evaluation of how accurately the numerical grid represents the geologic and hydrologic input); however, does apply and is discussed in the AMR. 1-D numerical grids (columns at borehole locations, lithologic information, and elevations were verified through comparison with stratigraphic information from the Geologic Framework Model 3.1. 2-D cross-sectional grids and 3-D grids were similarly verified. Spot checking (through hand calculations) of gridblock volumes, connection lengths, and interface areas between gridblocks, showed consistency with results calculated for all UZ model grids generated. Similar checks for the direction of absolute permeability confirmed vertical permeabilities for all connections within gridblock columns and horizontal permeabilities for all connections between gridblock columns.

AMR U0010 – Simulation of Net Infiltration for Modern and Potential Future Climates

The purpose of AMR U0010 is to provide spatially distributed, time-averaged estimates of net infiltration for Yucca Mountain in accordance with AMR DP TDP-NBS-HS-000036, Revision 0 (WP 81916105U3). The objective is to define the upper boundary condition for the site-scale 3-dimensional UZ Model under modern and potential future climate scenarios.

The infiltration model is a technically complex model that uses neutron borehole data, precipitation records, and data from stream gauges to produce estimates of infiltration under present day climate. When combined with future climate precipitation estimates, the model provides estimates of expected infiltration magnitudes and distribution under those conditions. Each climate stage is represented using a lower bound, a mean, and an upper bound climate and results in a corresponding net-infiltration scenario.

Improvements in INFIL, version 2.0, include code modifications to INFIL 1.0, updating of input parameters, calibration of the model based on stream flow records, and development of daily climate input representative of potential future climate stages.

However, despite these refinements, AMR U0010, draft 00A, has several software and technical deficiencies that need improvement:

1. Clarification of basis for technical interpretations, better editing of figures, and consistent symbolic representation of variables in equations and related figures is needed.
2. Data traceability needs to be improved. Although most efforts to trace data through the TDMS were successful, other inquiries could not be resolved even when key search words were employed.
3. In several cases, references supporting technical statements and model assumptions were not identified in the text or were not included in the list of references and the DIRS.
4. Some discussion of model uncertainty and limitations of the model results (as determined in AMR 0095, Analysis of Infiltration Uncertainty, should also be included in this AMR as a guide to users of the model results (Recommendation #2).
5. An underlying concern is that the work upon which this model is based (Flint et al, 1996, Conceptual and Numerical Model of Infiltration at Yucca Mountain) is unqualified.

The technical deficiencies are documented in DR USGS-00-D-034. The software deficiencies, which include the use of unqualified software and software routines/macros not adequately documented, are identified in DRs LVMO-00-D-038 and LVMO-00-D-039.

Validation for the scope and purpose of the model was determined to be sufficient. Estimates of infiltration for the nine climate scenarios were plotted against the corresponding average annual precipitation rates and compared with recharge and net infiltration estimates from independent sources. The qualitative comparison with the independent methods is based on the estimated average precipitation rate corresponding to a given recharge or net infiltration estimate. The graph of net infiltration and recharge versus precipitation indicates that the net infiltration estimates for all lower and mean climate scenarios are in general agreement with independent recharge estimates for precipitation rates of < 350 mm/yr. Some upper bound glacial transition and monsoon climate state values were found to be low relative to Maxey-Eaken recharge estimates. These upper bound monsoon and glacial transition climate net infiltration estimates compare more favorably with recharge estimates obtained using chemical analysis (sulfate and chloride) of groundwater at Yucca Mountain, as reported in the Saturated Zone Hydrochemistry AMR, Geochemical and Isotopic Constraints on Ground Water Flow Directions, Mixing, and Recharge at Yucca Mountain, Nevada. The method provides a spatially and temporally integrated flux estimate representative of maximum average net infiltration rates (including wetter paleoclimates).

AMR U0015 – *In Situ* Field Testing of Processes

The purpose of AMR U0015 is to document the data and subsequent analyses resulting from the ambient field testing activities performed in the Exploratory Studies Facility (ESF) in accordance with the AMR DP TDP-NBS-HS-000006, Revision 00 (WP 140120227M5). The principle objective of the testing program is to obtain data relevant to drift seepage and the conceptual model of matrix and fracture flow processes in the unsaturated zone.

The assumptions and approximations employed in this AMR for the air permeability calculations, liquid-release and seepage tests, fracture-matrix investigations, and moisture monitoring activities appear supportable and appropriate for their intended use. This AMR adequately describes the experimental setups and testing procedures for the locations and lithologies tested. Inspection of applicable SNs was conducted to examine supporting evidence for technical claims made in the AMR; no deficiencies or inaccuracies were noted. Efforts to trace and access data within the TDMS were generally successful. As such, the field testing and associated analyses documented in this AMR provide a sound basis for use as input to the seepage calibration model.

However, because of restricted spatial coverage (within or above the middle non-lithophysal unit of the TSw) and the limited temporal duration of the liquid-release tests, the reported analyses are only strictly applicable to those conditions and locations tested. Also, the effects of evaporation (due to tunnel ventilation) and the resulting impact to test performance are not well quantified (Recommendation #3).

Several other technical recommendations were made regarding this AMR. (Recommendation #4)

The AMR did include the use of software macros, which were not adequately documented in accordance with AP-SI.1Q, Rev. 2, ICN 4, “Software Management,” as described in DR LVMO-00-D-039.

Validation for the scope and purpose of the model was determined to be not applicable. This AMR is only concerned with the field testing and data collection activities; no modeling or model validation was attempted/required.

AMR U0080, Seepage Calibration Model

The purpose of this AMR is to document the development of the Seepage Calibration Model (SCM) based on available seepage testing data in accordance with AMR DP TDP-NBS-HS-00001, Revision 00 (WP 14012027M2).

The SCM is a template fracture continuum model that is developed based on air-permeability and liquid-release test data from niche studies of the ESF at Yucca

Mountain. The SCM provides a methodological and conceptual basis for the subsequent development of drift-scale seepage models. The work presented in this model is of good quality. Documentation of the work is good and the results are traceable and well presented. The results, however, have limited applicability and should only be used within the limits expressed by the range of parameters used to define the model, grid size, and water-release rates. The inverse modeling used in this AMR produced a product that has limited application to similar problems. The calculated capillary rise heights (approximately $1/\alpha$) are of the same order of magnitude as the grid block size. Larger grid block dimensions could produce a numerical artifact that inhibited seepage. Sensitivity studies on grid block size are needed to determine the limits of applicability of the results in this AMR. The authors and support staff were very helpful and responsive to discussions conducted during the audit. They demonstrated a good understanding of the QA program within the Yucca Mountain Project. However, the AMR did include the use of software, which was not properly controlled through Configuration Management as described in DR LVMO-00-D-036 and LVMO-00-D-037.

Validation for the scope and purpose of the model was determined to be sufficient. The ultimate purpose of the SCM is to predict seepage under natural conditions; however, due to the lack of data on seepage under natural percolation conditions, strict validation of the SCM cannot be performed. LBNL scientists have pursued an alternate approach using seepage data from four liquid-release tests different from those used to calibrate the SCM. The tests were performed using a wide variety of injection rates, and show both seepage threshold and potential storage effects. Seepage predictions were made for these tests and then compared to the resultant data, taking prediction uncertainty into account. The validation effort is considered successful if the data lie within 95% error band calculated by the calibrated SCM. This exercise resulted in model predictions, which are consistent with the measured seepage mass in most cases despite some rigorous assumptions regarding the uncertainty of the input parameters. The homogeneous models unconditionally meet the stringent validation criteria.

Heterogeneous models using the single realization of the random permeability field did not always fall within the 95% error band. Multiple realizations of the random permeability field would be required to provide a larger, more realistic spread of seepage predictions and further proof of validation.

Qualification of Data

As previously discussed in Subsection 5.1, CARs LVMO-99-C-001 and LVMO-98-C-002, there has been positive progress toward implementation of applicable procedures used as corrective action to resolve LVMO-99-C-001 regarding traceability of data to a controlled source. However, there has not been sufficient

implementation regarding confirmation of the quality of data produced prior to 06/30/99 to assess CAR-LVMO-98-C-002 corrective actions.

While reviewing SNs, there was a deficiency in implementation of AP-SIII.1Q, Rev. 0, "Scientific Notebooks," noted regarding the recording of reviews that was corrected during the audit (CDA #1).

There appears to be some confusion regarding implementation of AP-3.17Q, Rev. 0, "Impact Reviews," when data is superseded as discussed in Section 6.0 (Recommendation #5).

The DIRS list for AMR U0000 was found to be inaccurate and was CDA. There is a need for version control of the DIRS (CDA #2).

There has been limited activity in the qualification of data at this time, but the qualification of data process at LBNL appears to be performed satisfactorily; however, USGS failed to understand the DIRS process, as described in USGS-00-D-034. There is still need for overall improvement in this area.

Accuracy and Adequacy

The check copies of the three LBNL AMRs (U000, U0015 & U0080) were evaluated and the available checkers were interviewed. All comments and suggestions reviewed by the audit team appeared to be resolved satisfactorily. The checker's comments and originator's comment resolutions are color-coded and the Checkers Signature and Date indicated final acceptance of comment resolution for the AMRs. No conditions adverse to quality were identified. It should be noted that in accordance with LBNL procedures there was an additional technical check of each of their AMRs, which probably aided in the higher level of quality of these AMRs. No evidence of the checking process being performed was available for AMR U0010. USGS had identified this during a self-assessment performed 01/17/00 and initiated DR USGS-00-D-029. This DR coupled with the overall poor quality of the USGS AMR as documented in DR USGS-00-D-034, identified as a result of this audit, found the Adequacy & Accuracy portion of this audit unacceptable for the USGS AMR.

Three of these AMRs were in draft (only AMR U0000, Revision 00, had been issued at the time of the audit) and no impact reviews per AP-3.17Q, Rev. 0, "Impact Review," were required. This is based on e-mail from Dwight Hoxie to Bo Bodvarsson, et al, dated 10/26/99 @ 11:36 AM, in which the AP-3.17Q Subject Matter Expert, David Seamans, CRWMS M&O Engineering Document Control, stated, "No AP-3.17Q Impact Review is required for Rev 00 of the AMRs." Recommendation #4 in Audit Report M&O-ARP-00-01 was made to clarify Procedure AP-3.10Q, Rev. 2, "Analyses and Models," that no impact

review is required for AMRs that are original issues that are not superseding previously issued reports.

Independent reviews of three AMRs (U0010, U0015 & U0800) were performed in accordance with AP-2.14Q, Rev. 0, "Review of Technical Products." Review comments were documented as required, but have not been completely resolved with reviewers at the time of the audit. AMR U0000 did not receive an AP-2.14Q review. This was documented in a memo to file dated 9/21/99 from G. S. Bodvarsson.

Deliverables

Deliverables were reviewed during the audit by the audit team to determine availability and accuracy. The AMRs, SNs, and supporting documentation were found to be acceptable, traceable, and available upon request. The AMR check and review copies had been submitted to the Records Processing Center (RPC). Records at LBNL are well controlled and filed in a records storage room until they are forwarded to the RPC. LBNL retains a copy of the records forwarded to the RPC in their files.

5.5 Summary of Conditions Adverse to Quality

The audit team identified seven deficiencies during the audit, which resulted in the issuance of five DRs and two CDAs. These DRs are discussed in detail in Section 5.5.2. and the CDAs in Section 5.5.3.

5.5.1 Corrective Action Requests (CAR)

None

5.5.2 Deficiency Reports (DR)

USGS-00-D-034

AP-3.10Q requires the Originator to document the analysis/model in sufficient detail with identification of data and its sources to allow the model to be reproduced independently. However, the Infiltration Model (AMR U0010) is not sufficiently transparent as to the source, qualification, and definition of the equations and data sets to allow independent reproducibility. In addition, the inputs and their sources are required to be identified and documented in accordance with AP-3.15Q, Rev. 1, ICN 1, "Managing Technical Product Inputs," which requires the DIRS to adequately reflect the technical product input. The DIRS did not

list all the data used as input for this AMR, and the traceability of the data through the DIRS references is not specific enough to easily access the data.

Other requirements not met in developing this AMR include the DP, TDP-NBS-HS-000016, requirement for the use of a SN, but there was no evidence that a SN was used. Also, the required use of the AP-3.10Q, Attachment 3, "AMR Cover Sheet," was not completed for this AMR. In discussions with those personnel involved in the development of the AMR, it was not evident that they were aware of the latest procedural revision and changes to applicable procedures. AP-2.1Q, Rev. 0, "Indoctrination and Training of Personnel," requires that the manager ensure personnel are adequately indoctrinated and trained to achieve and maintain proficiency prior to performing the work.

LVMO-00-D-0036

Software was used in AMR U0080, "Seepage Calibration Model and Seepage Testing Data," without the source code or executable file being submitted to the SCS for baselining and release.

LVMO-00-D-0037

Software used in AMR U0080, "Seepage Calibration Model and Seepage Testing Data," was added to the projects Qualified Software Baseline list and status accounting system without the source code or executable files being received and verified by the SCS.

LVMO-00-D-0038

Software used in two of the AMRs evaluated was unqualified prior to the allowance of such use per AP-SI.1Q. After three months since the revision, these software codes were not processed in accordance with the requirements of the procedure for the controlled use of unqualified software.

LVMO-00-D-0039

All four of the AMRs evaluated used routines and/or macros. Of the 24 routines and macros reviewed, all had at least one, or more, anomalies in what was required to be documented in accordance with AP-SI.1Q. The anomalies ranged from not identifying the software identification and version number to lack of documentation to support the validation of the routine/macro.

5.5.3 Deficiencies Corrected During the Audit (CDA)

1. AP-3.10Q, Attachment 1, "Analysis/Model Documentation Outline," allows the use of SNs. Copies of SN pages are being made to support AMR data entries and a technical review of those pages is being conducted. The technical reviews of the SN pages were being maintained in a separate database and no entries made in the SNs as required by AP-SIII.1Q. LBNL took action during the audit to correct all the SNs. This was isolated to LBNL SNs and did not impact the quality of the products; therefore, it is considered a CDA.
2. AP-3.15Q, subsection 5.6.2, requires that when the final check and approval is completed, the DIRS is to be locked out so that no more changes can be made to the DIRS for that revision of the technical product. During this audit it was determined that the AMR U0000 latest DIRS list had eliminated two Macros that were listed in the DIRS for the approved revision 0 of the AMR. LBNL corrected the U0000 DIRS during the audit.

5.5.4 Follow-up of Previously Identified Deficiencies

During the audit, corrective action was evaluated with relation to the significant deficiencies documented in existing CARs that could impact the UZ AMR/PMR process.

CAR LVMO-99-C-001, Traceability of Data from Technical Report to TDMS, Checking Process, Technical Reviews

The three LBNL AMRs (U000, U0015 & U0080) had correct references to data shown on the DIRS list and, of the examples reviewed, the DIRS lists reflected the correct status of the data. LBNL personnel were correctly implementing the process to reflect traceability of data to a controlled source. AMR U0010 prepared by the USGS did not demonstrate traceability as described in DR USGS-00-D-034.

The check copies of the three LBNL AMRs were evaluated and the process found acceptable. It should be noted that, in accordance with LBNL procedures, there was an additional technical check of each of their AMRs, which probably aided in the higher level of quality of these AMRs.

For the USGS AMR, no evidence of the checking process being performed was available. This AMR had been forwarded for review in accordance with AP-2.14Q, "Review of Technical Products," without any prior check being accomplished and incorporated into the document.

USGS had identified this during a self-assessment prior to this audit and initiated DR USGS-DR-00-029. This DR coupled with the overall poor quality as documented in DR USGS-DR-00-034, identified as a result of this audit, found the adequacy and accuracy portion of this audit unacceptable for the USGS AMR.

Independent reviews of three AMRs (U0010, U0015 & U0800) were performed in accordance with AP-2.14Q; AMR U0000 did not receive an AP-2.14Q review. This was documented in a memo to file, dated 9/21/99, from G. S. Bodvarsson.

CAR LVMO-98-C-002

AP-3.15Q, Rev. 1, ICN 1, "Managing Technical Product Inputs," was revised, effective 12/15/99, to allow data to be classified and graded. This affected the status of implementation regarding this CAR. LBNL took the approach of preparing a list of Data Tracking Numbers (DTN) that support each of the 24 AMRs that support the UZ PMR and has proceeded to classify these DTNs into two categories: those that support the safety case (QL1) and those that do not support the safety case (QL2). When this review is completed, it will significantly reduce the number of DTNs that need a road map/checklist in accordance with AP-3.15Q. Preliminary estimates are that the number of DTNs that need a road map/checklist will be less than 100 rather than 278. However, this action of classifying and grading data has slowed progress toward actual implementation of clearance of TBVs. No completed road map/checklists were provided during the audit. In other words, for this particular audit there was a lack of implementation regarding the process described in AP-3.15Q to clear TBVs.

CAR LVMO-98-C-006

CAR-006 corrective action resulted in establishing a centralized process for qualifying and controlling project software codes that are subject to the requirements of the Quality Assurance Requirements Document. The process was established with the issuance of AP-SI.1Q, Rev. 1, dated 05/03/99. The CAR-006 corrective action response and established process required that all Responsible Managers identify and turn over to the centralized Software Configuration Secretariat (SCS) any software that has or will be used in quality-affecting work. The SCS would account for the software, place it on the Qualified Software Baseline list, if qualified, and control the software use through status accounting. Contrary to the above, a code was identified as being used in a UZ AMR without the source code or executable code being submitted to the SCS for baselining

or release. The problem was further compounded by the fact that this software was added to the projects Qualified Software Baseline list and status accounting system without the source code or executable code being submitted to the SCS for baselining or release. Upon further investigation it was determined that there were approximately 43 other software products which currently reside on the Qualified Software Baseline list and status accounting system in which the source code or executable file have not been submitted or received and verified by the SCS. Prior CRWMS M&O management commitment to the CAR corrective actions and procedure AP-SI.1Q stipulates that software used on the project needs to be derived from the centralized CM prior to use. These deficiencies are identified in DRs LVMO-00-D-036 and LVMO-00-D-037.

The original intent of CAR-006 and process procedure AP-SI.1Q was that software would be qualified prior to being used in any quality-affecting work. The AP-SI.1Q procedure was revised on 10/15/99 to provide a methodology for using software prior to it being fully qualified, as a special dispensation granted by the U.S. Department of Energy Project Operations Review Board. This process required a special set of controls and documentation to be prepared and placed under configuration control to properly status the software development activity, as well as the software use, in an unqualified state. During the audit, which was held three months after the issuance of AP-SI.1Q, Revision 2, it was identified that several of these codes were not in accordance with Section 5.12 of the procedure. These deficiencies are identified in DR LVMO-00-D-038.

Part of the CAR-006 corrective actions was to develop the process methodology, AP-SI.1Q, to control software development. Part of the development methodology includes a reduced level of effort to document software that is categorized as either software routines or macros. The reviews performed on software routines and/or macros during the audit did not place as much emphasis on how these were documented as it did on what was documented. Contrary to the process requirements and regardless of where they needed to be documented, e.g., technical product, data submittal, SN, Software Routine Report, every software routine or macro reviewed, i.e., 24, had at least one, if not more, anomalies in what was suppose to be documented. These anomalies ranged from:

- not identifying the identification and version number of the software routine,
- not identifying the identification and version number of the commercial code used to write the routine/macro, and/or
- lack of documentation to support the validation of the routine/macro.

These deficiencies are identified in DR LVMO-00-D-039.

As a result of this audit and previous PMR audit results, CAR-006 will be closed, based on the effectiveness of the process established. However, a new CAR LVMO-00-C-001 will be issued for the failure by the CRWMS M&O, National Laboratories, and the USGS to effectively implement the process in place, and to manage and control the use of software. Any outstanding deficiencies from CAR LVMO-98-C-006 will be rolled into one of the four DRs being issued during this audit.

LVMO-99-C-010

The model validation for the four AMRs was adequate in accordance with AP-3.10Q. The details to support this conclusion are provided for each AMR summary in Section 5.4, "Methodology".

6.0 RECOMMENDATIONS

1. AMR U-0000, "Numerical Grids for UZ Flow & Transport Model" - A statement should be added to Section 6.7, Dual-Permeability Grid Generation, of the AMR for the equations (Eq. 3 to Eq. 7) on page 55 describing development of the equations from the Warren & Root reference to improve transparency. (LBNL)
2. AMR U0010, "Infiltration Model" – The AMR as presented for the audit, does not discuss the uncertainty and the predictability of the infiltration. The uncertainty analysis being developed, as AMR U0095 should be discussed within the Infiltration Model AMR and that the AMR authors communicate with each other regarding each other's results. (USGS)
3. AMR U0015, "In-Situ Field Testing of Processes" - The effects of evaporation on the water release tests should be documented in the AMR. The limitation on the data as a result should be more transparent in the conclusions for use by others. Recommendations should be made to minimize the evaporation effects through longer-term experiments and better isolation of the test area; i.e. bulkheads. (LBNL)
4. AMR-U0015, "In-Situ Field Testing of Processes" - Future field activities concerned with seepage testing in other repository units (i.e., TSw lower lithophysal in the Cross-Drift), should employ lower liquid-release rates, longer test periods, and better control of ventilation and humidity effects. Efforts to assess lateral diversion due to excavated drifts/niches should also be included. Reference to the qualitative pre-test predictions of whether seepage would be observed in the individual water-release tests should be included to demonstrate confidence in the testing approach. (LBNL)

5. For U-0000 Numerical Grids for UZ Flow & Transport Model, the CRWMS M&O superseded two DTNs in October and impact analyses had not been initiated in accordance with AP-3.17Q. Impact analyses have now been initiated for these two DTNs. AP-SIII.3Q, Rev 0, ICN 2 (effective 12/15/99), "Submittal and Incorporation of Data to the Technical Data Management System," now refers to AP-3.17Q for impact analysis for superseded data; however, AP-3.17Q and AP-III.3Q are not clear regarding who is responsible for initiating an impact analysis of superseded data. Recommend CRWMS M&O take action to 1) ensure superseded DTNs are tracked and impact analyses are performed in a timely manner and 2) clarify the process within the APs. (CRWMS M&O)
6. AMRs should identify limitations to end users of data. These limitations should be transparent to ensure correct applicability in future use. A section should be included in the AMRs to provide recommendations to improve technical adequacy. (All)

7.0 LIST OF ATTACHMENTS

Attachment 1: Personnel Contacted During the Audit

Attachment 2: Summary Table of Audit Results

Attachment 3: Summary Table of Audit Results for Procedure Compliance Evaluations

ATTACHMENT 1

PERSONNEL CONTACTED

| Name | Organization/Title | Pre-Audit Meeting | Contacted During Audit | Post-Audit Meeting |
|---------------------|---|-------------------|------------------------|--------------------|
| Aden-Gleason, Nancy | LBNL/Environmental Assessment Manager | X | X | X |
| Andrews, Robert | M&O/Performance Assessment Operations Manager | | | X |
| Benton, Hugh | M&O/Waste Package Operations | | | X |
| Bodvarsson, G.S. | LBNL/Project Manager | X | X | X |
| Burningham, Andrew | Natural Environment Program Operation | | X | X |
| Carter, Ted | USNRC/Observer | X | | X |
| Ciocco, Jeff | USNRC Observer/Technical Representative | X | | X |
| Cook, Paul | LBNL | | X | |
| Craig, Robert | USGS, Technical Project Officer | | X | X |
| Cushey, Mark | LBNL/Program Coordinator | X | X | X |
| Cuzner, Marlene | LBNL/Records Coordinator | X | X | |
| Dove, F. Harvey | OQA/QATSS, QA Representative | | | X |
| Eshleman, Michael | OQA/Senior QA Specialist | X | | X |
| Fedors, Randy | CNWRA/USNRC Observer | X | | X |
| Finsterle, Stefan | LBNL/Scientist | X | X | X |
| Fissekidou, Vivi | LBNL/Environmental Assessment Specialist | X | X | X |
| Flint, Alan | USGS/Field Testing | X * | X | |
| Flint, Lorraine | USGS/Scientist | X * | X | |
| Fray, Russ | M&O/SAIC Support Operations Manager | | | X |
| Greene, Hank | OQA/QATSS Manager, Quality Systems | | | X |
| Harris, Stephen | OQA/LBNL/On-Site Representative | X | | X |
| Hasson, Robert | OQA/QATSS, Lead Audits | | | X |
| Haukwa, Charles | LBNL/Unsaturated Zone & Transport Models | | X | |
| Hayes, Larry | NEPO Operations Manager | X | X | X |
| Hevesi, Joe | USGS/Hydrology and Climate | X* | X | |
| Hinds, Jennifer | LBNL/Analysis & Modeling Report Originator | X | X | X |
| Howard, Robert | M&O Data & Code Project Manager | | | X |
| Hoxie, Dwight | NEPO/USGS Office Manager | | | X |
| Hunt, David | Management & Technical Services | | | X |
| Jordan, Jeff | USGS/QA Implementation Specialist | X * | X | |
| Kersch, Keith | SAIC/Technical Specialist | X | X | X |
| Lau, Peter | LBNL/Project Control | X | | |
| Latta, R. M. | USNRC/Observer | X | | X |
| Linden, Ronald | Management Technical Support/Golder/ Senior Geoscientist | X | X | X |
| Link, Suzanne | LBNL/Technical Data Coordinator | X | X | X |
| Mangold, Donald | LBNL/Software Configuration Manager | X | X | X |
| McClung, Ivelina | LBNL/Measuring & Test Equipment Custodian | X | | X |
| McDaniel, Mary | OQA/QATSS, Senior QA Representative | | | X |
| McKinley, Pat | USGS Data Coordinator | | X | |

| Name | Organization/Title | Pre-Audit Meeting | Contacted During Audit | Post-Audit Meeting |
|--------------------|---|-------------------|------------------------|--------------------|
| Miller-Corbett, C. | USGS Software Specialist | X * | X | |
| Parks, Bruce | USGS/Implementation Team Chief | X * | X | X |
| Patterson, Russ | Office of Project Execution/Physical Scientist | | | X |
| Pelletier, John | M&O/Sandia National Laboratories, Technical Staff | | | X |
| Pentleton, Martha | M&O/Regulatory & Licensing | | X | |
| Persoff, Peter | LBNL/Checker | X | X | |
| Powe, Richard E. | OQA/Senior QA Specialist | X | | X |
| Schreiner, Randy | M&O/Engineered Barrier Systems Operations | | | X |
| Simmons, Ardyth | LBNL/Project Manager | | X | X |
| Snell, Dick | M&O/Repository Systems Operation | | | X |
| Stambaugh, Roberta | CRWMS M&O | | X | |
| Stover, Richard | LBNL/Checker | X | X | X |
| Stroupe, E. P. | M&O/TRW, Manager, Repository Systems Operation | | | X |
| Trautz, Rob | LBNL/Res. Associate | X | X | |
| Tsang, Yvonne | LBNL/Senior Staff Scientist | | | X |
| Wagner, Lester | OQA/Senior QA Specialist | X | | X |
| Wang, Joseph S. | LBNL/Staff Scientist | X | X | X |
| Woods, Mary | CRWMS M&O, Engineering Document Control | | X | |
| Younker, Jean | M&O/TRW, MGR Deputy Technical | | | X |
| Zinkevich, Fred | M&O/Project Manager, QA Coordination | | | X |

* Additional Pre-audit meeting held for USGS personnel on 1/26/2000

LBNL – Lawrence Berkeley National Laboratory
 M&O – Management and Operating Contractor
 NEPO – Natural Environment Program Operations
 QA – Quality Assurance
 OQA – Office of Quality Assurance
 QATSS – Quality Assurance Technical Support Services
 SAIC – Science Applications International Corporation
 USGS – U. S. Geological Survey
 USNRC – U. S. Nuclear Regulatory Commission

ATTACHMENT 2

SUMMARY TABLE OF AUDIT RESULTS

| Critical Process Steps | Details Checklist | Deficiencies | Recommendations | Process Effectiveness | Product Adequacy | Overall |
|--------------------------------|-------------------|--|-----------------|-----------------------|------------------|---------|
| Resources | Pgs. 2-13 | | | | | |
| Planning | Pgs. 2-4 | | N/A | SAT | SAT | SAT |
| Personnel | Pgs. 5-6 | USGS-00-D-034 | N/A | SAT | SAT | SAT |
| Equipment/ Software | Pgs. 6-13 | LVMO-00-D-036 LVMO-00-D-037 LVMO-00-D-038 LVMO-00-D-039 | N/A | UNSAT | UNSAT | UNSAT |
| Methodology | Pgs. 14-52 | | | | | |
| AMR U0000 | Pgs. 14-22 | LVMO-00-D-038 LVMO-00-D-039 | 1 | SAT | SAT | SAT |
| AMR U0010 | Pgs. 22-33 | USGS-00-D-034 LVMO-00-D-038 LVMO-00-D-039 | 2 | UNSAT | UNSAT | UNSAT |
| AMR 0015 | Pgs. 34-43 | LVMO-00-D-039 | 3 & 4 | SAT | SAT | SAT |
| AMR 0080 | Pgs. 44-52 | LVMO-00-D-036 LVMO-00-D-037 | N/A | SAT | SAT | SAT |
| Qualification of Data | Pgs. 53-58 | USGS-00-D-034 CDA # 1 CDA # 2 | 5 | SAT | SAT | SAT |
| Adequacy & Accuracy | Pgs. 59-68 | USGS-00-D-034 | N/A | SAT | SAT | SAT |
| Deliverables | Pgs. 69-70 | N/A | N/A | SAT | SAT | SAT |

ATTACHMENT 3

SUMMARY TABLE OF AUDIT RESULTS FOR PROCEDURE COMPLIANCE EVALUATIONS

| QARD Element | Implementing Document | Details Checklist | Deficiency Reports | CDA | Recommendations | Program Adequacy | Procedure Compliance | Overall |
|--------------|-----------------------|----------------------------------|--|-----|---------------------|------------------|-------------------------|------------------------|
| 2.0 | AP-2.1Q | Pg. 5 | USGS-00-D-034 | N/A | N/A | SAT | UNSAT USGS SAT LBNL | UNSAT USGS SAT LBNL |
| | AP-2.2Q | Pg. 6 | N/A | N/A | N/A | SAT | SAT | SAT |
| | AP-2.13Q | Pgs. 2-4 | N/A | N/A | N/A | SAT | SAT | SAT |
| | AP-2.14Q | Pg. 61 & 65-66 | N/A | N/A | N/A | SAT | SAT | SAT |
| | AP-2.15Q | Pgs 2-4 | N/A | N/A | N/A | SAT | SAT | SAT |
| 3.0 | AP-3.4Q | Pg. 67 | N/A | N/A | N/A | SAT | SAT | SAT |
| | AP-3.10Q | Pgs. 14-52 Pgs. 59-61 & 68 | USGS-00-D-034 | N/A | # 1, 2, 3, 4, and 6 | SAT | UNSAT USGS SAT LBNL | UNSAT USGS SAT LBNL |
| | AP-3.15Q | Pgs. 53-55 | USGS-00-D-034 | #2 | N/A | SAT | UNSAT USGS SAT LBNL* | N/I* |
| | AP-3.17Q | Pg. 62 & 66 | | N/A | #5 | SAT | SAT | SAT |
| 17.0 | AP-17.1Q | Pgs. 69-70 | N/A | N/A | N/A | SAT | SAT | SAT |
| Supp I | AP-SI-1Q | Pgs. 6-13 | LVMO-00-D-036 LVMO-00-D-037 LVMO-00-D-038 LVMO-00-D-039 | N/A | N/A | SAT | UNSAT | UNSAT |
| Supp III | AP-SIII.1Q | Pgs. 63-64 | N/A | #1 | N/A | SAT | SAT | SAT |
| | AP-SIII.2Q | Pgs. 55-57 | N/A | N/A | N/A | SAT | N/I | N/I |
| | AP-SIII.3Q | Pg. 58 | | N/A | N/A | SAT | SAT | SAT |

* LBNL partially implemented AP-3.15Q; however, did not demonstrate enough implementation of that portion of the AP-3.15Q devoted to clearance of TBVs to assess procedural implementation. Meanwhile, USGS failed to understand the DIRS process as described in DR USGS-00-D-034 and also did not demonstrate enough implementation of that portion of the AP-3.15Q devoted to clearance of TBVs to assess procedural implementation.